HYDROCRACKING OF SYNTHETIC OILS

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INTRODUCTION

Synthetic oils derived from coal, oil shale and tar sands differ significantly in composition from petroleum crudes. The coal oils contain large amounts of oxygenated compounds and aromatic hydrocarbons and the shale oils contain large quantities of nitrogen compounds. Because of the differences in composition the synthetic oils may pose some new problems in their processing as compared to the conventional processing of petroleum oils. Hydrocracking is a versatile processing method and it will play an important role in the processing of synthetic oils as evidenced by the published date (1-4). In the present communication, the data on some aspects of hydrocracking of coal, shale and tar sand oils are presented.

EXPERIMENTAL

MATERIALS: The coal oil was obtained by the hydrogenation of a high volatile bituminous coal from Utah. The shale oil was obtained by insitu retorting. The tar sand oil was prepared by solvent extraction of tar sands found in Utah. A dual functional Catalyst was used for hydrocracking the synthetic oils.

EQUIPMENT

Hydrocracking was carried out in a continuous bench scale fixed Reactor System (4). The products were evaluated by standard methods. The heat of the reaction was calculated from the heats of combustion of raw materials and products.

RESULTS AND DISCUSSION

The product distributions and the severities of hydrocracking mainly depends upon the composition of the feed stocks and the processing conditions. The data in Table I indicates that the coal oil is more aromatic in nature when compared to the shale and tar sand oils as shown by the H-C atomic ratios. The coal oil also contains more heterocompounds and asphaltenes. The data in Table II indicates that the coal oil is a more refractory feed stock when compared to the shale and tar sand oils. This appears to be due to the higher aromatic and asphaltene contents of the coal oil. The hydrocracking severities seem to be somewhat related to the aromaticity of the feed stocks. The data in Table III indicates that the yield of Naphtha depends upon the total conversion irrespective of the type of feed stock used. The three feed stocks yielded almost the same quantities of Naphtha at equal conversion levels. However, the gas yield was high in case of shale oil while the coal oil yielded relatively more coke. The composition of Naphtha and gas depend upon the nature of the feed stock as indicated by the data in Table IV. The coal of Naphtha is more aromatic and will have a higher octane rating when compared to the Naphthas from shale and tar sand oils. It is evident from the foregoing discussion that aromatic feed stocks need more severe process conditions but they produce better quality naphthas.

The data in Table V indicates that hydrogen consumption varies with the nature of the feed stock and is directly proportional to the conversion in all the three cases. The consumption of hydrogen in coal oil hydrocracking is higher than the consumption in tar sand oil processing which in turn is more when compared to shale oil processing. This again seems to be related to the aromaticity of the feed stocks. The hydrocracking reactions are exothermic and the heat of the reaction varies with the nature of the feed stock and conversion as shown by the data in Table V. Coal oil hydrocracking produces more exothermic heat when compared to tar sand oil which in turn gives more heat when compared to shale oil. The reaction heat seems to be also related to the aromaticity of the feed stock.

The first order rate constants of the hydrocracking of coal, shale and tar sand oils were found to be respectively represented by equations 1 to 3.

$$K_c = 0.52 \times 10^4 \, e^{-16,200/RT} \quad hr.^{-1} \quad (1)$$

$$K_s = 0.12 \times 10^5 \, e^{-14,300/RT} \quad hr.^{-1} \quad (2)$$

$$K_t = 1.05 \times 10^4 \, e^{-15,100/RT} \quad hr.^{-1} \quad (3)$$

Where K_c K_s K_t represent reaction rate constants for the hydrocracking of coal, shale and tar sand oils respectively.

ACKNOWLEDGEMENT

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TABLE I - PROPERTIES OF FEED STOCKS

	Coal Oil	Shale Oil	Tar Sand Oil
Gravity, °API	0.75	20.2	17.3
Viscosity, SUS, 80°C	205	180	220
S, Wt. %	0.43	0.85	0.34
N + O, Wt. %	3.84	2.14	1.84
H/C (Atomic)	1.06	1.81	1.62
Asphaltene, Vol. %	30.0	2.0	2.5
Distillation, °C			
1. B. P.	200	200	200
50% distillate	348	334	319

TABLE II - HYDROCRACKING PRODUCT DISTRIBUTION

Temp: 480°C, Pressure: 2000 P.S.1.
Space Velocity: 0.96

	Coal Oil	Shale Oil	Tar Sand Oil
Yield of Products, Vol. %			
Naphtha	60.0	68.0	66.0
Gas	9.5	14.0	12.0
Coke	5.1	4.0	6.0
Recycle Oil	27.0	14.5	17.5
Severity	0.7	0.82	0.78

TABLE III - HYDROCRACKING PRODUCT DISTRIBUTION

Conversion, Vol. %	20	40	60	80
Naphtha Yield				
Coal Oil	15	32	48	65
Shale Oil	16.5	35	48	63.5
Tar Sand Oil	15.5	32	47.5	64.0
Gas Yield				
Coal Oil	2.5	5.0	8.0	10.5
Shale Oil	2.0	6.0	9.0	13.0
Tar Sand Oil	3.5	6.0	8.5	11.0
Coke Yield				
Coal Oil	0.5	2.0	4.0	5.6
Shale Oil	0.5	1.6	2.7	4.0
Tar Sand Oil	0.5	2.0	3.6	5.0

TABLE IV - COMPOSITION OF NAPHTHA AND GAS

Temp: 480°C, Pressure: 2000 P.S. 1.
Sp. Vel: 0.96

	Coal Oil	Shale Oil	Tar Sand Oil
Composition of Naphtha, Vol. %			
Saturates	75.2	40.2	49.5
Olefins	2.8	3.1	2.5
Aromatics	22.0	56.7	48.0
Composition of Gas, Vol. %			
CH_4	16.0	13.0	12.0
C_2H_6	28.0	27.0	28.0
C_3H_8	42.0	40.0	37.0
C_4H_{10}	14.0	20.0	22.0

TABLE V - HYDROGEN CONSUMPTION AND REACTION HEAT IN HYDROCRACKING

Conversion, Vol. %	30	50	60	80
H_2 Consumption, SCF/BBL				
Coal Oil	600	1020	1240	1660
Shale Oil	380	720	900	1230
Tar Sand Oil	350	720	910	1290
$\Delta H \times 10^3$, BTU/BBL				
Coal Oil	47	80	96	130
Shale Oil	34	58	70	96
Tar Sand Oil	32	60	75	104